

## MANATEE VOCALIZATION DETECTION METHOD AND SYSTEM

Origin of the Invention

5           The invention described herein was made in the performance of official duties by an employee of the Department of the Navy and may be manufactured, used, licensed by or for the Government for any governmental purpose without payment of any royalties thereon.

Field of the Invention

10           The invention relates generally to detection of underwater sounds, and more particularly to a method and system for detecting manatee vocalizations in the water.

Background of the Invention

15           The West Indian manatee is a large, plant-eating aquatic mammal that congregates for much of the year in shallow coastal areas and warmwater canals. Unfortunately, these are also the locations traversed by many recreational and commercial vessels. As a result, the manatee is being injured and killed by collisions with vessel hulls and propellers.

20           In an effort to reduce such collisions, a variety of solutions have been proposed and/or tried. The solutions include regulating vessel speeds in areas frequented by manatees, performing aerial surveillance during specified times (e.g., boat races, times of high boat traffic, during times of high performance boat/motor testing, etc.),

25           instituting a moratoria on permits for marinas and other facilitates in areas frequented by manatees, and various forms of manatee detection schemes such as use of volunteer

30

"spotters", signals between boaters and acoustic detection. Obviously, a robust mechanized method of manatee detection is the preferred approach. However, the high noise environment of shallow coastal waters has, thus far, led to acoustic  
5 detection schemes having high false alarm rates. Detection schemes with high false alarm rates lead to unnecessary boat maneuvering and, over time, a loss of user confidence in the detection scheme.

10 Summary of the Invention

Accordingly, it is an object of the present invention to provide a method and system for detecting the presence of manatees in a water environment.

15 Another object of the present invention is to provide a method and system for detecting the presence of manatees in high-noise shallow-water environment.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

20 In accordance with the present invention, the detection of manatee vocalizations begins with the detection of sounds in an underwater region. After a digital representation of the sounds is generated, sounds at unwanted frequencies are filtered out resulting in the generation of filtered data in  
25 a frequency range of interest. A plurality of overlapping time-windowed portions of the filtered data are then formed.

For each time-windowed portion, a power spectrum for frequency bins in the frequency range of interest is estimated. Each such power spectrum is then normalized using  
30 an average of power spectrums calculated over a plurality of the frequency bins. As a result, a normalized spectrum value is defined for each frequency bin with each normalized

spectrum value associated with broadband noise having a value that is less than that associated with narrowband tones. Next, for each of the overlapping time-windowed portions, normalized spectrum values indicative of narrowband tones that occur (i) in windows of frequency bins encompassing frequencies lower and higher than each of a lowest resonant frequency (associated with manatee vocalizations) and its harmonics and (ii) with a specified degree of variance with respect to frequency separation therebetween, are filtered out. As a result of this filtering step, a resulting number of normalized spectrum values indicative of narrowband tones are maintained. Each normalized spectrum value that is not filtered out is assigned to a frequency-based harmonic set. A scoring routine is applied that uses the normalized spectrum value in each harmonic set. A manatee vocalization is indicated when a threshold score is achieved across at least a portion of the overlapping time-windowed portions.

#### Brief Description of the Drawings

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. 1 is a block diagram of a system used for the detection of manatee vocalizations in accordance with the present invention; and

FIG. 2 is a top-level flow diagram of a method used to detect manatee vocalizations in accordance with an embodiment of the present invention.

Detailed Description of the Invention

Referring now to the drawings, and more particularly to FIG. 1, a system for detecting manatee vocalizations in accordance with the present invention is shown and is referenced generally by numeral 10. In general, system 10 includes one or more hydrophone(s) 12 placed in an underwater region of interest, e.g., in the vicinity of a marina, in a shipping channel, on the hull or just below a surface vessel, on or towed behind a submerged vessel, etc. The analog output of hydrophone(s) 12 is supplied to a local or remotely-located signal processor 14 which performs a number of signal processing operations thereon. Signal processor 14 supplies an output when manatees are detected to one or more alarm system(s) 16 to generate one or more of a visual, audible and tactile type of alarms. The particular hardware used to construct system 10 can be selected from a wide variety of components as would be well understood by one of ordinary skill in the art. Accordingly, the particular hardware used to implement the present invention is not a limitation thereof.

Signal processor 14 encompasses a number of processing operations which can be achieved by one or several processing components. Accordingly, it is to be understood that the separate blocks shown in the drawings are solely for purposes of facilitating an explanation of the present invention. The analog output from hydrophone(s) 12 is first converted into a digital signal representation thereof at an analog-to-digital (A/D) conversion block 141. The digital signals are then passed through a passband filtering block 142 so that only the broad frequency range associated with manatee vocalizations. Typically, this frequency range is approximately 1600 Hz to

18 KHz.

The digitized, bandpass filtered data is then split into overlapping time-windowed data blocks at time windowed data formation block 143. Each data block has a time duration less than or equal to that of a typical manatee vocalization or approximately 0.175 seconds or less. A power spectrum estimation block 144 processes each time-windowed data block to, in general, provide an estimate of the power spectrum thereof in the frequency domain. Each power spectrum value associated with each frequency bin is then normalized at block 145. The output sequence generated by normalization results in values having a mean of 1.0 when broadband noise is the input and a larger mean when the input is a narrowband tonal signal. A noise suppression filtering block 146 evaluates the narrowband tonal signals as a function of their frequency bins and operates to suppress those signals that are from closely-spaced frequency bins. Finally, the remaining narrowband tonal signals are scored at a rule-based detection scheme block 147. Each time the rule based scheme is satisfied over a number of overlapping time-windowed data blocks, one or more of alarm system(s) 16 are activated.

Referring now additionally to FIG. 2, one embodiment of the method of the present invention will be explained in greater detail. An analog output 100 from hydrophone(s) 12 is converted to digital data at step 102. The digital data is bandpass filtered at step 104 to filter out all frequencies other than those in the range of typical manatee vocalizations which typically ranges between 1600 Hz and 18 KHz. The resulting digital data is then split into overlapping time-windowed data blocks at step 106. The time or length of each time window of data is selected to be less

than or equal to that of a typical manatee vocalization or less than or equal to 0.175 seconds. The amount of overlap is selected to assure the capture near the start of a manatee vocalization and is typically on the order of 75% of the window length.

The time-windowed, bandpass filtered digital blocks of data are processed in four stages broadly illustrated by steps 108, 110, 112 and 114. Note that the second and third stages may be performed in an iterative fashion.

The first stage (step 108) involves power spectrum estimation of each time-windowed portion of the data received from step 106. A variety of power spectrum estimation techniques can be used without departing from the scope of the present invention. By way of illustrative example, the well-known periodogram technique is applied in the illustrated embodiment. Briefly, as is known in the art, each time-windowed portion of the data is split into smaller overlapping time-windowed blocks at step 1080. Next, step 1082 performs a Fast Fourier Transform (FFT) on each of the smaller windows of data to convert same into the frequency domain. Finally, at step 1084, an estimation of the power spectrum as a function of frequency bins is formed by taking the average of the squares of the FFTs.

The second stage (step 110) of processing in the present invention involves normalizing each power spectrum in an effort to suppress broadband noise while maintaining narrowband tones indicative of typical manatee vocalizations.

This second stage also suppresses the effects of changes in broadband ambient noise conditions while maintaining the narrowband structure of manatee vocalizations.

Once again, a variety of normalization schemes can be used without departing from the present invention. By way of

1.0 whereas the presence of a narrowband tone in a frequency bin results in a normalized value that is (generally significantly) greater than 1.0.

5       The third stage (step 112) of processing involves the application of a noise suppression technique that evaluates the spacing between frequency bins containing narrowband tones. The goal of noise suppression is to maintain narrowband tones indicative of manatee vocalizations while suppressing narrowband tones indicative of noise and  
10       broadband noise not removed by the normalization process. Typical manatee vocalizations have a lowest resonant frequency (at which their amplitude is high) and successive resonant frequencies (at which amplitude eventually falls off). Accordingly, when narrowband tones are indicated by  
15       the results of step 110, the frequency at which the narrowband tones occur is evaluated in terms of resonant frequencies of interest in an effort to reduce false alarms.

      More specifically, step 1120 provides (i.e., user selected/provided) one or more lowest resonant frequencies of  
20       interest depending on the background noise characteristics, type of manatee, age of manatee, sex of manatee, etc., that is of particular interest. Next, at step 1122, closely-spaced narrowband tones occurring in windows of frequency bins that are above and below each of the lowest resonant  
25       frequency and its harmonics are filtered/suppressed. As used herein, the phrase "closely-spaced narrowband tones" refers to a high degree of variance in the occurrence of narrowband tones within the above-noted windows of frequency bins. For  
30       example, if a lowest resonant frequency of 1600 Hz was provided at step 1120 (with harmonics at 3200 Hz, 4800 Hz, etc.), the closeness or variance with respect to the occurrence of narrowband tones occurring in windows of

frequency bins that encompass frequencies that are lower and higher than (but not including) each of 1600 Hz, 3200 Hz, 4800 Hz, etc., is evaluated. A high degree of variance within these windows results in suppression of such narrowband tones. The size of the windows (of frequency bins) and the level of acceptable or unacceptable variance are predetermined by the user. In step 1122, filtering or suppression can be accomplished by resetting the normalized power spectrum value at that frequency bin to a value of 1.0.

The fourth and final stage (step 114) of processing involves scoring the narrowband tone data. Prior to applying the scoring routine, step 1140 assigns each remaining frequency bin having a normalized powerspectrum value indicative of a narrowband tone to a harmonic set based upon the frequency of the frequency bin. Each harmonic set is defined by a base frequency and resonance thereof. Next, step 1142 orders the normalized values for each harmonic set based on the magnitude thereof, i.e., largest to smallest. Next, at step 1144, two requirements are checked for each harmonic set's base frequency. By way of example, the first requirement is that either (i) two or more significant harmonics of the harmonic set's base frequency exist (e.g., the values at the harmonics are indicative of the spectrum level for the narrowband tone) or (ii) the value of the largest harmonic minus one is less than or equal to a percentage (e.g., 5%) of the second largest harmonic component minus one. The second requirement is that the resonant frequencies associated with the largest and second largest ordered values (i.e., output from step 1142) correspond to two of the four lowest resonant frequencies of a harmonic set.

If either of these requirements is not satisfied, the



harmonic set is assigned a score of zero at step 1146. If the requirements are satisfied for a harmonic set, then the harmonic set has a score computed at step 1148. Such scoring could generate an average value that is computed over the harmonic set's resonances. Note that such averaging could limit participation in the average to those frequencies having (normalized power spectrum) values that are within some percentage of the highest value for the harmonic set. With each harmonic set having a score (i.e., either assigned at step 1146 or computed at step 1148), step 1150 selects one harmonic set based on its score as an output. For example, the harmonic set achieving the highest score could be selected. The above-described scoring stage (step 114) is performed for each of the overlapping time-windowed portions of data. If, at step 116, a threshold score is achieved across one or more time-windowed portions of the data thereby indicating the presence of a manatee, an alarm signal is issued at step 118. As described above, the alarm can be visual, audible and/or tactile in nature.

The advantages of the present invention are numerous. Manatee vocalizations are autonomously detected in a way that significantly reduces false alarms. Accordingly, "manatee alarms" generated by the present invention will have a high degree of confidence associated therewith.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is claimed as new and desired to be secured by

NAVY CASE 84804

PATENT

Letters Patent of the United States is: